ehp

LESSON:

Diesel Fuels Duke It Out

Summary: Students analyze results from a research study on petroleum diesel and biodiesel to determine how these fuels differ in terms of hazardous emissions. Then students compare the results of the study to a summary article on biodiesel.

Lesson Type: Data Analysis—Students read and interpret data from tables. Focus Lesson—This lesson uses in-depth information from the *EHP Student Edition* article.

EHP Article: "Biodiesel: Cultivating Alternative Fuels"
EHP Student Edition, May 2007, p. A86–A91
http://www.ehponline.org/docs/2007/115-2/focus-abs.html

Objectives: By the end of this lesson, students should be able to

1. calculate averages and percentage changes;
2. analyze and compare data in a table showing the emission rates of hazardous pollutants from different types of vehicles using petroleum diesel and biodiesel fuels; and
3. explain the advantages and disadvantages of using biodiesel.

Class Time: 45–60 minutes

Grade Level: 9–12

Subjects Addressed: Biology, Environmental Sciences, General Science, Health

Prepping the Lesson (15 minutes)

INSTRUCTIONS:

1. Download the entire May 2007 *EHP Student Edition*, or download just the article "Biodiesel: Cultivating Alternative Fuels" at http://www.ehponline.org/docs/2007/115-2/focus-abs.html.
2. Review the Background Information, Instructions, and Student Instructions.
3. Read the article "Biodiesel: Cultivating Alternative Fuels."
4. Make copies of the *EHP Student Edition* article and Student Instructions.

MATERIALS (per student):

- 1 copy of the May 2007 *EHP Student Edition* or 1 copy of "Biodiesel: Cultivating Alternative Fuels," preferably in color
- 1 copy of the Student Instructions
- Calculator

VOCABULARY:

- alternative fuels
- B2
- B5
- B20
- B100
- biodiesel
- bioreactors
- catalyst
- diesel
- glycerin
- transesterification
- ultra-low sulfur diesel (ULSD)
- viscous

National Institute of Environmental Health Sciences

BACKGROUND INFORMATION:

Sufficient background on biodiesel is supplied in the *EHP Student Edition* article and Student Instructions. The results in the tables in the Student Instructions were selected from average emission test results reported in the National Renewable Energy Laboratory (NREL) report titled *Effects of Biodiesel Blends on Vehicle Emissions* (McCormick et al., 2006). This report summarizes the results of testing eight heavy-duty on-road diesel vehicles using petroleum diesel fuel and B20, a blend of 80% petroleum diesel and 20% soy-derived biodiesel. The eight test vehicles included three transit buses, two school buses, two Class 8 heavy-duty tractor trailers, and one motor coach. These vehicles were selected to represent a variety of engine makes, sizes, emission control technologies, and transmission types, with model years ranging from 2000 to 2006 and accumulated mileage ranging from 2,274 to 503,468. Because the eight vehicles were tested in a special facility under simulated conditions rather than on the open road, these data may not be representative of actual "in-use" heavy-duty vehicles.

Vehicles were tested under a variety of conditions on a heavy-duty dynamometer. Different drivers followed pre-set driving traces displayed on a computer monitor in the cab of the vehicle. Fuel was precisely metered into the engine, and emissions analyzed used Environmental Protection Agency (EPA) standard protocols. The effects of the following variables were examined in the study: type of vehicle, driving cycles, drivers, and fuel used. Driving cycles included urban scenarios (slow speed, lots of stop-and-go, idling) and freeway scenarios (continuous higher speed, on-and off-ramp acceleration/deceleration). Driver variables attempted to account for variation in driver style mostly related to acceleration and stopping.

All vehicle results were reported as the averages of three or more individual test runs. The NREL report concluded that "on average, B20 caused PM and CO emissions to be reduced by 16% to 17% and HC emissions to be reduced by 12% relative to petroleum diesel" (p. iii). Oxide of nitrogen (NO_x) emissions, however, "varied with engine/vehicle technology and test cycle ranging from –5.8% to +6.2%" (p. iii). The use of B20 appeared to have no net impact on NO_x emissions. For additional details, consult the NREL report.

Only selected average results of a series of test runs for the three transit buses (identified as #1, #2, and #3), the school bus without the diesel particle filter, and the motor coach were used in the *EHP Student Edition* lesson for the purposes of illustrating the test results. Test run conditions were similar for each vehicle when comparing petroleum diesel fuel results with results for B20. The average emission and miles-per-gallon results were taken from the following matched tables in the NREL report: 25 and 26 (Transit Bus #1), 27 and 28 (Transit Bus #2), 29 and 30 (Transit Bus #3), 41 and 42 (motor coach), and 49 and 50 (conventional school bus).

When discussing the result with the students, it is important to consider the following: 1) There is no consideration in the lesson of the errors or deviations in the data. Thus, the small changes between the NO_x emissions and the fuel economy may fall within the standard deviation (meaning there is no real difference between the two); and 2) There are numerous variables that can potentially impact emissions and fuel economy including terrain, fuel quality, vehicle type, tire type, how well tuned a vehicle is, weather, and outside temperature.

Reference:

McCormick RL, Williams A, Ireland J, Brimhall M, Hayes RR. 2006. Effects of biodiesel blends on vehicle emissions (Milestone Report NREL/MP-540-40554). Golden, CO: National Renewable Energy Laboratory; available: http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/40554.pdf.

RESOURCES:

Environmental Health Perspectives, Environews by Topic page, http://ehp.niehs.nih.gov/. Choose Carbon Monoxide, Nitrogen Oxide (NO_x), Particulate Matter, Transportation/Fuels

American Lung Association, Diesel exhaust and air pollution, http://www.lungusa.org/site/pp.asp?c=dvLUK9O0E&b=36089

Clean Diesel Fuel Alliance, http://www.clean-diesel.org/

National Biodiesel Board, http://www.biodiesel.org/

U.S. Department of Energy, Alternative Fuels Data Center, http://www.eere.energy.gov/afdc/

U.S. EPA, Transportation and air quality, http://www.epa.gov/oms/

Implementing the Lesson

INSTRUCTIONS:

1. Tell students they are going to investigate the advantages and disadvantages of using biodiesel.
2. Have students complete the Student Instructions, working either individually or in small groups.
3. Lead a class discussion about their results. Refer to the Background Section for additional talking points.

NOTES & HELPFUL HINTS:

1. Part of the lesson could be done as homework.
2. The lesson could be expanded by having the students do the following additional extension activities: research the local availability of biodiesel fuels; research buying a car that can use biodiesel fuels; research how to make your own biodiesel fuel from used cooking oil; invite a guest speaker who uses biodiesel; and research the possibility of using biodiesel in the school's buses.

Aligning with Standards

SKILLS USED OR DEVELOPED:

- Communication (note-taking, oral, written—including summarization)
- Comprehension (listening, reading)
- Computation
- Critical thinking and response
- Research
- Tables and figures (creating, reading)

SPECIFIC CONTENT ADDRESSED:

- Environmental health
- Alternative fuels
- Percent changes
- Biodiesel
- Hazardous emissions

NATIONAL SCIENCE EDUCATION STANDARDS MET:

Science Content Standards

Unifying Concepts and Processes Standard

- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement
- Evolution and equilibrium
- Form and function

Science as Inquiry Standard

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Life Science Standard

- Interdependence of organisms
- Matter, energy, and organization in living systems

Science and Technology Standard

- Abilities of technical design
- Understanding about science and technology

Science in Personal and Social Perspectives Standard

- Personal and community health
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

History and Nature of Science Standard

- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

Assessing the Lesson

Step 1: The attached tables show selected results of this study using petroleum diesel fuel (Table 1) and B20, a mixture of 80% petroleum diesel fuel and 20% biodiesel (Table 2). Calculate the totals and averages for each column for both tables,and fill in the appropriate rows. Also, calculate the percent changes from Table 1 to Table 2 for the averages of each column, and fill in the appropriate row in Table 2.

Table 1: Pollutant Emissions from Diesel Vehicles Using Petroleum Diesel Fuel

Type of Diesel Vehicle	NO_x (grams/mile)	THC (grams/mile)	CO (grams/mile)	PM (grams/mile)	Fuel Economy (miles per gallon)
Transit Bus #1	19.80	0.871	3.60	0.2740	4.67
Transit Bus #2	19.44	0.794	3.43	0.3210	4.54
Transit Bus #3	19.78	0.824	3.04	0.3079	4.60
Motor Coach	7.75	0.230	4.05	0.2538	6.63
Conventional School Bus	9.78	0.373	8.95	0.6954	5.01
Total	76.55	3.092	23.07	1.8521	25.45
Average	15.31	0.618	4.61	0.3704	5.09

Table 2: Pollutant Emissions from Diesel Vehicles Using 80% Petroleum Diesel Fuel and 20% Biodiesel

Type of Diesel Vehicle	NO_x (grams/mile)	THC (grams/mile)	CO (grams/mile)	PM (grams/mile)	Fuel Economy (miles per gallon)
Transit Bus #1	18.65	0.625	2.63	0.2264	4.56
Transit Bus #2	18.67	0.571	2.73	0.2150	4.45
Transit Bus #3	19.04	0.592	2.48	0.2447	4.51
Motor Coach	7.96	0.190	3.15	0.1825	6.54
Conventional School Bus	10.39	0.300	6.93	0.5284	4.99
Total	74.71	2.278	17.92	1.3970	25.05
Average	14.94	0.456	3.58	0.2794	5.01
% Change Between Table 1 & 2 for Averages	–2%	–26%	–22%	–25%	–2%

Step 2: How does the presence of 20% biodiesel in the fuel affect the emission of pollutants and the fuel efficiency of the vehicles?

Emissions for all four pollutants are, on average, reduced in the buses and motor coach when using 20% biodiesel. Unfortunately, fuel economy is also reduced.

Step 3: a. Are the results consistently reduced for all four pollutants for all five vehicles?

Emissions for THC, CO, and PM are consistently lower for all five vehicles when using biodiesel. NO_x is decreased for the transit buses when using biodiesel, but not for the motor coach and conventional school bus.

b. How does the consistency of results relate to your confidence in the results?

The more consistency between results, the greater the confidence there would be in the THC, CO, and PM results.

c. How might inconsistencies impact your interpretation of the results, especially with small changes in percentage (e.g., 1% or 2% changes)?

The small change of –2% reduction in NO_x combined with the inconsistency in reduction for different vehicle types decreases our confidence that there is any real difference between petroleum diesel and biodiesel for NO_x emissions.

Step 5: Does the article agree with the results from the National Renewable Energy Laboratory results reported in Tables 1 and 2?

The article reported that B20 fuel reduces THC, CO, and PM by at least 10%. The National Renewable Energy Laboratory (NREL) results show reductions over 20%. So the article and NREL results are in agreement in that they both indicated use of B20 reduces emissions for these three pollutants. The article, however, reported increases in NO_x emissions of 2% using B20, while the NREL tables showed the opposite.

NOTE: It would be useful to discuss error or standard deviation with students with respect to the differences in NO_x emissions as reported by the article and the NREL results. If the standard deviation is ±2%, then there is no real difference between the NO_x emissions of biodiesel and petroleum diesel.

Step 6: Outline the advantages and disadvantages of using B20 fuel.

Advantages:

1. Reduces dependence on foreign oil.
2. Produces less PM, THC, and CO emissions.
3. The source of the fuel is renewable.
4. Since biodiesel contains carbon from plants, it doesn't add more carbon dioxide to the atmosphere when it is burned.
5. B20 contains no sulfur, a source of acid rain and health problems.
6. Small amounts of biodiesel (B2 and B5) act as lubricant in the ultra-low sulfur diesel.

Disadvantages:

1. May increase NO_x emissions.
2. Production may divert agriculture from food, leaving some people hungry.
3. Special heating systems are required for engines in extreme cold when using B100.
4. B100 has strong solvent properties that liberate rust and other engine contaminants, which could plug filters and fuel ejectors.
5. Fuel quality has been poor, not meeting ASTM standards.

Step 7: Should the use of biodiesel fuel be increased? Explain.

Answers will vary. Look for a clearly articulated position with logical support arguments.

Authors and Reviewers

Authors: Barry Schlegel and Laura Hemminger, University of Medicine and Dentistry of New Jersey–School of Public Health
Reviewers: Stephanie Bishop, Susan Booker, Erin Dooley, Stefani Hines, and Joseph Tart

Give us your feedback! Send comments about this lesson to ehpscienceed@niehs.nih.gov.

STUDENT INSTRUCTIONS: Diesel Fuels Duke It Out

Step 1: Biodiesel is an alternative fuel made from plants. Its increased usage is expected to reduce dependence on foreign oil. There is concern, however, that the use of biodiesel may increase pollution. A study was conducted by the National Renewable Energy Laboratory to look at emissions of oxides of nitrogen (NO_x), total hydrocarbons (THC), carbon monoxide (CO), and particulate matter (PM) from three different transit buses (identified as Transit Bus #1, #2, and #3), a motor coach, and a school bus. The tests were conducted using simulated driving conditions. NO_x and THC react together in sunlight to form ground-level ozone. NO_x, PM, and ozone cause acute and chronic lung problems. CO causes cardiovascular and central nervous system effects.

The attached tables show selected results of this study using petroleum diesel fuel (Table 1) and B20, a mixture of 80% petroleum diesel fuel and 20% biodiesel (Table 2). Calculate the totals and averages for each column for both tables, and fill in the appropriate rows. Also, calculate the percent changes from Table 1 to Table 2 for the averages of each column, and fill in the appropriate row in Table 2.

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Total					
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Step 2: How does the presence of 20% biodiesel in the fuel affect the emission of pollutants and the fuel efficiency of the vehicles?

Step 3: a. Are the results consistently reduced for all four pollutants for all five vehicles?

b. How does the consistency of results relate to your confidence in the results?

c. How might inconsistencies impact your interpretation of the results, especially with small changes in percentage (e.g., 1% or 2% changes)?

Step 4: Read the article "Biodiesel: Cultivating Alternative Fuels."

Step 5: Does the article agree with the results from the National Renewable Energy Laboratory results reported in Tables 1 and 2?

Step 6: Outline the advantages and disadvantages of using B20 fuel.

Step 7: Should the use of biodiesel fuel be increased? Explain.